

On-farm Evaluation of Manual Well Driller for Shallow Groundwater in Western Oromia, Ethiopia

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ABSTRACT

The art and science of manually drilling involves the use of human strength and resources to obtain groundwater. A significant portion of the population in developing nations cannot afford the high cost of machine-drilled wells. If not lined properly, hand-dug wells frequently collapse. Thus, this study's objective was to assess manual well drillers on-farm for efficient groundwater use in the Jimma Zone's Dedo, Jimma, and Omo Nadda. The hard, impermeable subsurface could be reached by the Driller. The driller in this investigation dug down to a depth of 24 meters. A maximum of six human resources were needed. At the various locations of Dedo, Jimma, Omo Nadda I, and Omo Nadda II, the depth of drilling and time required were (2.83 hours, 9.5 m), (11 hours, 24 m), (7.3 hours, 12.2 m), and (2.6 hours, 10.12 m), respectively. The driller's capacity to drill grows with depth since it takes longer and requires more manpower. The duration and depth of the drilling at the particular location are directly correlated. Because of the impermeable layer, it is advised that extra caution be used when manufacturing the cutting tip. According to field observations, it is preferable to switch from a manual driller to one that is powered by an engine or motor because the input from operators showed that the driller became more challenging as the depth increased.

Keywords: Manual Well Drilling; Shallow Groundwater; Low-Cost Technology; Rural Water Supply; Oromia; Ethiopia; Borehole; Irrigation; Hydraulic Performance; Water-Lifting Devices; Development Cost; Depth Efficiency; Driller Evaluation; Community-Based Drilling.

1. Introduction

Manual well drilling was first used in Ethiopia to promote family irrigation, but more recently, the technology has also been used to develop domestic water supplies. Depending on their needs, individuals utilize the manually drilled wells for drinking, irrigation, and livestock watering. About 82.8 million people live in rural Ethiopia, where 83 percent of them reside, and 52 percent of them are impoverished (IFAD). Enhancing the agricultural output and water availability of smallholder farmers can boost their earnings, enhance food security, and supply water for domestic and livestock requirements. Manually drilled wells are one way to provide dependable and reasonably priced access to shallow groundwater resources. After drilling a well and having access to water, farmers can use a range of pump options (such as motorized pumps or treadle pumps) to draw water from the well, a variety of water storage technologies, and a variety of water application techniques (such as sprinklers or drip irrigation) to irrigate crops. Ethiopia lacks widespread access to manual well drilling, even though it is common and highly developed in several Asian nations.

In Ethiopia, double-cropping is done along rivers, although single-cropping is the norm. In agricultural production, which is primarily rain-fed subsistence farming, women are crucial. The present irrigated land is only about 7–10% of the 3.7–4.3 million hectares (Mha) of potential irrigable area (FAO, 2012).

Gaining access to groundwater for both male and female farmers can boost their incomes, improve food security, and make it easier for them to get water for their homes and animals. Although it is not commonly available in Ethiopia, private sector manual well drilling is frequently a dependable and reasonably priced way to obtain shallow groundwater.

An inventive, low-cost method for groundwater development is manual drilling, in which the hole is drilled by hand.

A significant portion of the population in developing nations cannot afford the high cost of machine-drilled wells. Drilling "shallow" water wells (down to around 35 meters) by hand is an additional option that can lower well costs by a factor of 4–10 in comparison to machine-drilled boreholes. In addition to allowing governments and non-governmental organizations to build more water wells, this cost decrease makes it possible for farmers, schools, small communities, and villagers to have their wells built by the private sector (Van der Wal, 2010).

The art and science of manually drilling involves the use of human strength and resources to obtain groundwater. It is a method that seeks to produce a hole in the ground that is deep enough to reach the water table. Another name for it is hand drilling. Other names for hand drilling include manual drilling, human-powered drilling, and occasionally just "low-cost drilling." Hand drilling technologies, as their names imply, rely heavily on human power. Hand drilling allows the operators to stay above the earth and drill a narrow well, as opposed to hand digging, which necessitates a person to be physically below ground to dig the well (in Ethiopia, the well is typically 1.2 m in diameter, with the use of concrete rings and occasionally masonry linings diameter borehole (50-200mm). Drilled depths depend on the technology and soil formation, but can reach 50 m or more.

Manual drilling teams encounter issues with site selection, soil determination, logging, well installation, well development, water quality, well yield (well flow rate), and loss of working water in various nations. When the drilling process is not fully understood, these issues could arise. The deepest well that IDE has personally bored in Ethiopia is 47 meters. More than 500 wells have been drilled by iDE since January 2009 in the Oromia, SNNPRS, and Amhara regions; nearly all of these wells are for irrigation, and the pumps installed are washer, rope, and other inexpensive pumps that iDE built.

Because hand-dug wells can hold water that seeps in through the well walls overnight, they are less expensive and highly effective in formations with poor permeability. However, because the water comes from an open source that makes it easy for pollutants to enter, the overall yield per day can be minimal, and the water quality might be subpar. Additionally, poorly lined hand-dug wells frequently collapse. The yield is high for a hand-dug well that is encased with concrete rings to keep it from collapsing, but the cost will be very high. Therefore, using a manual drill is advised for good drilling. Furthermore, ADPLAC identified well drilling technology issues or demand as a significant issue in the region. In light of this, this research was conducted to evaluate the performance of manual well drillers for the wise utilization of groundwater under farmers' conditions.

1.1. General Objective

To evaluate the technical performance, operational feasibility, and field applicability of a manual well driller for accessing shallow groundwater under real farm conditions in Western Oromia, Ethiopia.

1.1.1. Specific Objectives

1) To assess the drilling depth, time, and human power required for manual well drilling across different soil types and locations (Jimma, Dedo, and Omo Nadda).

- 2) To measure the water yield (discharge) from manually drilled wells and analyze its suitability for irrigation and domestic use.
- 3) To evaluate the relationship between drilling depth, working time, and labor needs under varying field conditions.
- 4) To identify operational challenges and gather user feedback on manual drilling, including the effectiveness of the cutting tip and working water requirements.
- 5) To provide recommendations for design improvement and potential upgrading to motorized or engine-powered systems based on observed limitations.

2. Materials and Methods

2.1. Materials

Materials used were: GI drill pipes, different size pipe diameters, wrenches, Angle iron, a container, and working water.

2.2. Method

2.2.1. Study Area

Three areas of the Jimma Zone—Jimma Town, Dedo, and Omo Nadda—in the Oromia Regional State of southwest Ethiopia were chosen for the study. These regions were picked because of their potential for shallow groundwater, diversity of soil types, and significance to smallholder farming groups.

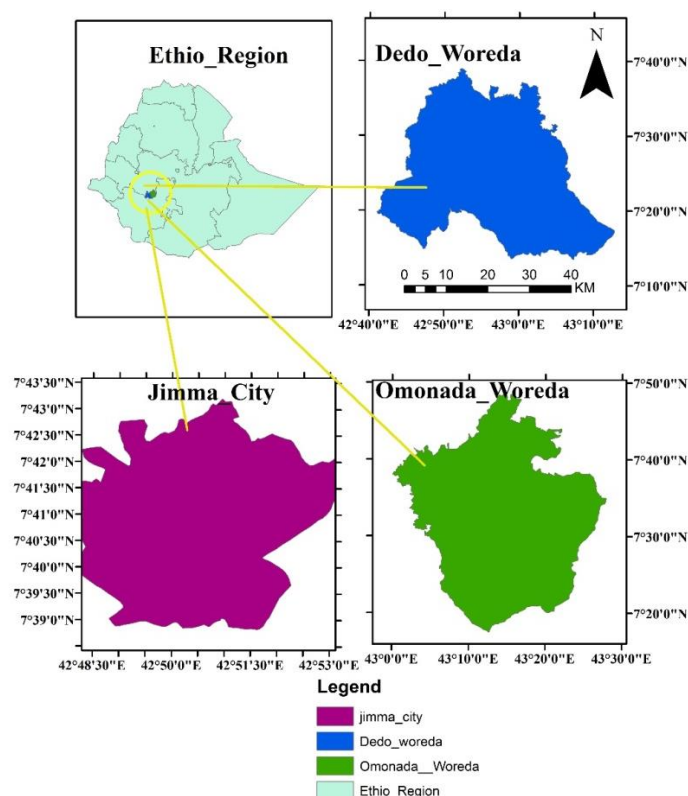


Figure 1. Study area maps

The Jimma Zone has an elevation of 1,650 to 2,200 meters above sea level and is located between latitudes 7°15'N and 8°56'N and longitudes 35°52'E and 37°37'E. With temperatures usually between 12°C and 28°C and an average annual rainfall of 1,200 mm to 2,000 mm, the climate is categorized as humid subtropical. May through October is when the primary rainy season occurs.

The study area is suited for manual drilling due to its topographic characteristics, which include gentle, flat, and undulating landscapes. These districts are situated in the Gilgel Gibe basin, which is dominated by the following soil types: Nitisols, Acrisols, Ferralsols, Vertisols, and Planosols (Van Ranst et al., 2011). The texture, structure, and permeability of these soils vary, which affects borehole stability and drilling ease.

The chosen locations are representative of Ethiopian smallholder farming systems, where having access to reasonably priced groundwater supplies is crucial. These circumstances created the perfect setting for assessing the manual well drilling technology's performance, limitations, and viability in actual field settings.

2.2.2. Soil of the Study Area

The elevation spans from 1650 to 2200 meters above sea level, and the terrain is gentle, level, and undulating. Van Ranst et al. (2011) state that the primary reference soil classes in the Gilgel Gibe catchment are nitisols, acrisols, ferralsols, vertisols, and planosols. The mid- and high-altitude soils have a decreased nutrient content due to their lengthy history of human land use (SLMP, 2009).



Figure 2. Soil type at the study site

2.2.3. Descriptions of the Driller

The driller has different components: Valve, cutting tip, drilling pipe, handle, support, and seat.



Figure 3. Part of the drilling

2.2.4. Drilling site selection

Sites were selected from the Jimma zone. Before the drilling of a new well starts, a good drilling site were selected. In most cases the villagers or owner of the new well was point out a location which was suitable for them as users. From all districts five sites were selected based some Criteria like ground water table.

2.2.5. Actions Taken into consideration

1.5", 3.5", and 5.5" diameter drilling bits, as well as 24-meter-long 1.5" GI drill pipes, pipe wrenches, and other minor instruments, were utilized in the sludging procedure. The time it took to finish the well was measured based on the depth and type of formation, and the drillers had expertise drilling wells with a diameter of 1.5" to 5.5".

Numerous factors needed to be taken into consideration during the drilling process to keep things from going wrong. Important procedures that take place below ground level while drilling must be taken into consideration in addition to the actual drilling abilities that were carried out at ground level. While drilling might not be possible to pass through stones, wells that have been dug may collapse during construction, especially in places with clay soil. While failed manually drilled wells are easily concealed, abandoned excavated wells can leave scars on the landscape. Drilling water (working water) may run off or, worse, the borehole may collapse, burying some of the drilling apparatus. Lastly, when the hole has been bored, the sanitary seals, screen, and well casing should be installed at the right depth, preventing contaminated water from entering and ensuring a sufficient yield.

2.3. Working Principle

Water circulation was used for sludging to raise the cuts to the surface. They shifted the drill pipes up and down. The drill bit impacts loosen the soil on the downstroke, and a valve on the top of the pipe closes on the upstroke, drawing water through the pipe and carrying the cuttings to the surface. The water squirts into a pit in front of the well when the valve opens the pipe's top on the subsequent downward stroke. While the water overflows from the pit back into the well, the cuttings in this pit separate from the water and settle out. Water pressure keeps the borehole open. It is possible to add thickeners (additives) to the water to prevent collapse and reduce loss of working water (drill fluid). Sludging (with or without rotation) was used up to depths.

2.4. Data collected and Field tests

- Drilling Depth
- Time taken to drill
- Human power need
- Well yield or Discharge
- Soil sample at different depths per meter

(a) Discharge

The discharge in m^3/s is calculated by dividing the amount of water filled into the known volume by the measured time. The discharge was calculated by Eq. (1):

$$Q = \frac{V}{T} \quad \dots(1)$$

Where: Q discharge of the pump, L/s

V = volume of water to fill the measuring drum, L

T = time required to fill the drum, s

2.5. Data management and statistical analysis

The collected data were analyzed using descriptive statistical tools.

3. Results and Discussion

3.1. Time Taken to Drill at the Dedo Site

For depths ranging from 2 to 5 meters, the observed drilling time at the Dedo site varied between 49 and 58 minutes. The number of workers ranged from two to six, depending on the formation and resistance of the soil. Interestingly, a significant rise in the number of workers needed for a comparatively short depth of 2.5 meters points to the possibility of rocky or compacted soil. Accordingly, in regions with diverse subsurface conditions, a more flexible or durable tool design is required, as soil texture has a substantial impact on drilling performance (Van der Wal, 2010; Weight, Yoder, & Keller, 2013).

Table 1. Result of well drilling obtained at the Dedo site

Time taken (min)	Water consumed in liters	Human power	Dawn ward Depth from ground surface (m)
49	610	2	5
58	365	3	2
54	60	6	2.5

3.2. Time Taken to Drill at Jimma Site

Drilling times at Jimma varied from 44.2 to 84 minutes, while drilling depths ranged from 1.2 to 3.2 meters. Water use and labor requirements were proportionate to depth, as was to be expected. These differences highlight the connection between operational efficiency and subsurface resistance. Increased drilling resistance brought on by stoniness or compacted soil is consistent with research from SLMP (2009) and Van Ranst et al. (2011), which highlights the necessity of careful resource allocation and manpower planning as drilling depth increases.

Table 2. Result of the well driller obtained at Jimma

Time taken (min)	Dawn ward Depth from ground surface (m)	Watering in litter	Human power
44.2	2.8	95	1
33	3.2	100	2
51	3.1	240	3
72	2.4	300	3

60	2.9	250	3
68	2.1	220	3
64	1.8	180	3
72	1.6	170	3
76	1.4	160	4
78	1.2	150	4
84	1.5	130	4

3.3. Cumulative Time versus Depth

Expected physical labor needs were reflected in the continuous positive association between total drilling time and depth. There was a discernible drop in efficiency as drilling continued over 10 meters. The proposals of Arjen Van der Wal (2010) and IWMI (2013), which promote partial mechanization or alternative low-cost powered drilling options for deeper depths, are supported by this exponential increase in time and resource consumption. 0.84 lit/min was the well discharge that was obtained.

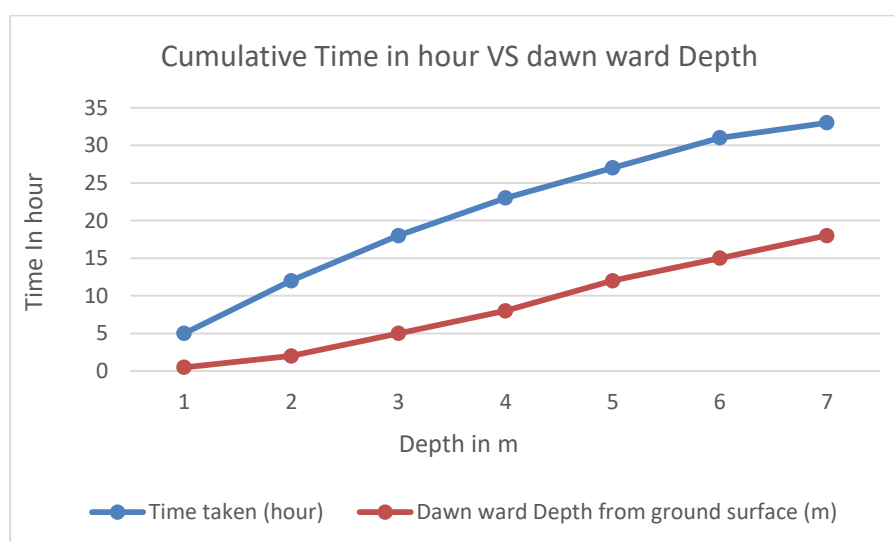


Figure 4. Cumulative time vs. dawn ward depth

3.4. Discharge Rate and Drilling Time Relationship

All locations had an average discharge rate of 0.84 L/min, which is a moderate output appropriate for household or small-scale irrigation. This discharge level may not be sufficient for major agricultural enterprises unless combined with water storage or effective application technologies like drip irrigation, even though it is sufficient for basic water needs. Furthermore, because of hydrogeological limitations such as aquifer yield and permeability, discharge rates do not directly scale with drilling depth (Ravikumar et al., 2011; Foster & Chilton, 2003).

3.5. Performance at Omo Nadda I and II Sites

For depths ranging from 0.3 to 3.0 meters, drilling data from Omo Nadda I revealed considerable water use, up to 1760 liters, with up to four people participating. In contrast, under comparable working conditions, Omo Nadda II's water consumption peaked at 250 liters. This variance suggests a variety of soil types, which are probably more

porous or broken in Omo Nadda I and cause a higher working water loss. The significance of initial hydrogeological evaluations before drilling is highlighted by these site-specific variations (UNICEF, 2010; Hanjra & Qureshi, 2010).

Table 3. Results of the well driller obtained at Omo-Nadda I

Time taken (min)	Dawn ward Depth from ground surface (m)	Water in litter	Human Power
68	2.3	315	1
120	3	1050	2
106	3	1760	3
40	0.3	785	3
75	3	870	4
31	0.6	490	4

Table 4. Result of well drilling obtained at Omo Nadda II

Time taken (min)	Dawn ward Depth from ground surface (m)	Watering in liters	Human power
4.50	1.80	95	2
35.78	2.35	120	2
7.04	1.50	180	3
8.00	1.50	210	3
27.45	1.55	240	3
29.90	1.52	240	4
9.10	1.14	250	4
60.00	2.90	250	4

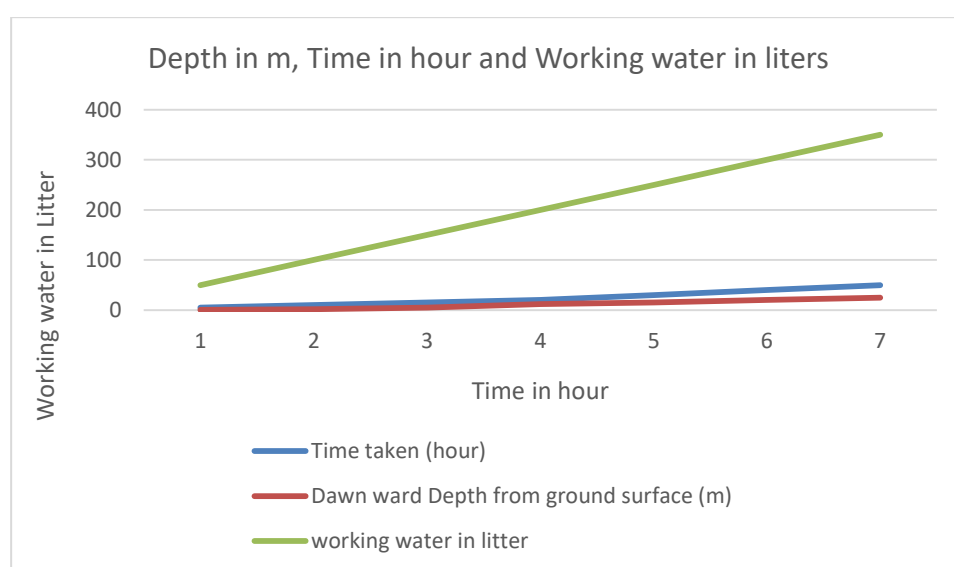


Figure 5. Dawn ward depth in meters vs. time in hours, as shown from the above figure, the result revealed that the dawn ward drilling depth (m) increases the time taken (hours) and working water increases, which shows there is a direct relationship

4. Conclusion and Recommendation

An on-farm assessment was conducted in the Jimma Zone at Dedo, Jimma, and Dedo and Omo Nadda. The hard, impermeable subsurface could be reached by the driller. Because it was dug down to a depth of 24 meters. A maximum of six human resources were needed. It takes an average of 0.84 lit/min of water to sophisticate the soil. At the various locations of Dedo, Jimma, Omo Nadda I, and Omo Nadda II, the drilling depth and time were 2.83 hours, 9.5 meters, 11.23 hours, 24 meters, 7.3 hours, 12.2 meters, and 2.6 hours, 10.12 meters, respectively. The driller's capacity to drill grows with depth since it takes longer and requires more manpower. The duration and depth of the drilling at the particular location are directly correlated. It is advised that extra caution be used when manufacturing the cutting tip and that drilling is stopped when the impermeable layer appears. It is important to examine the working water. According to field observations, it is preferable to switch from a manual driller to one that is powered by an engine or motor, since the operator has reported that the driller becomes more challenging as the depth increases.

5. Future Recommendations

The following are some future recommendations concerning this study:

- 1) Examine the durability and long-term performance of manually dug wells in various soil types.
- 2) Examine the possibility of incorporating inexpensive automation into technologies for manual drilling.
- 3) Evaluate how community-managed well drilling affects rural livelihoods on a socioeconomic level.
- 4) Perform field tests that compare conventional mechanized systems with manual drilling.
- 5) Assess how widespread manual well drilling in delicate habitats affects the environment.

Declarations

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Competing Interests Statement

The authors have declared that no competing financial, professional, or personal interests exist.

Consent for publication

All the authors contributed to the manuscript and consented to the publication of this research work.

Authors' contributions

All the authors took part in literature review, analysis, and manuscript writing equally.

Availability of data and materials

Supplementary information is available from the authors upon reasonable request.

Institutional Review Board Statement

Not applicable for this study.

Informed Consent

Not applicable for this study.

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